UNIVERSITY OF TWENTE.

SAXION

# CAES

## Computer Architectures for Embedded Systems

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- Optimal district heating supply temperature case Meppel Nieuwveenselanden
- Optimal capacities: renewable generators and storage facilities
- Interesting advantages of district heating systems for integration of renewable energy

# Focus of CAES energy group

Energy-autonomous smart micro-grids:

- Modeling and control of energy streams in micro-grids
- TRIANA control methodology for micro-grids based on
  - Prediction
  - Planning
  - Real-time control

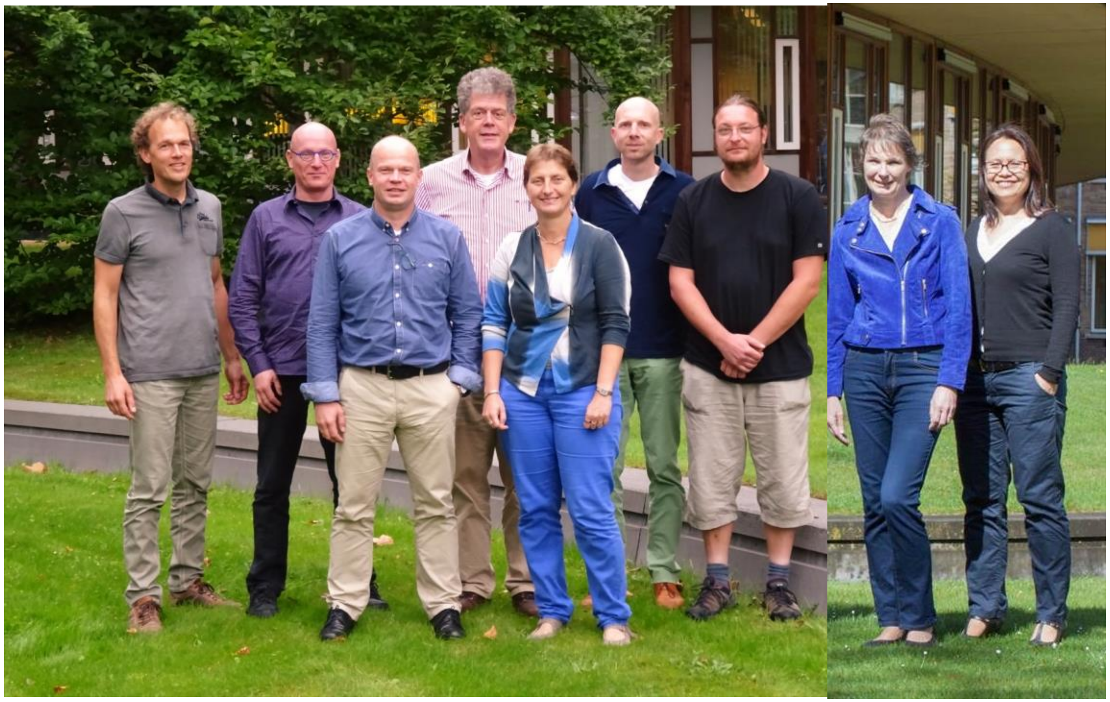
Main applications:

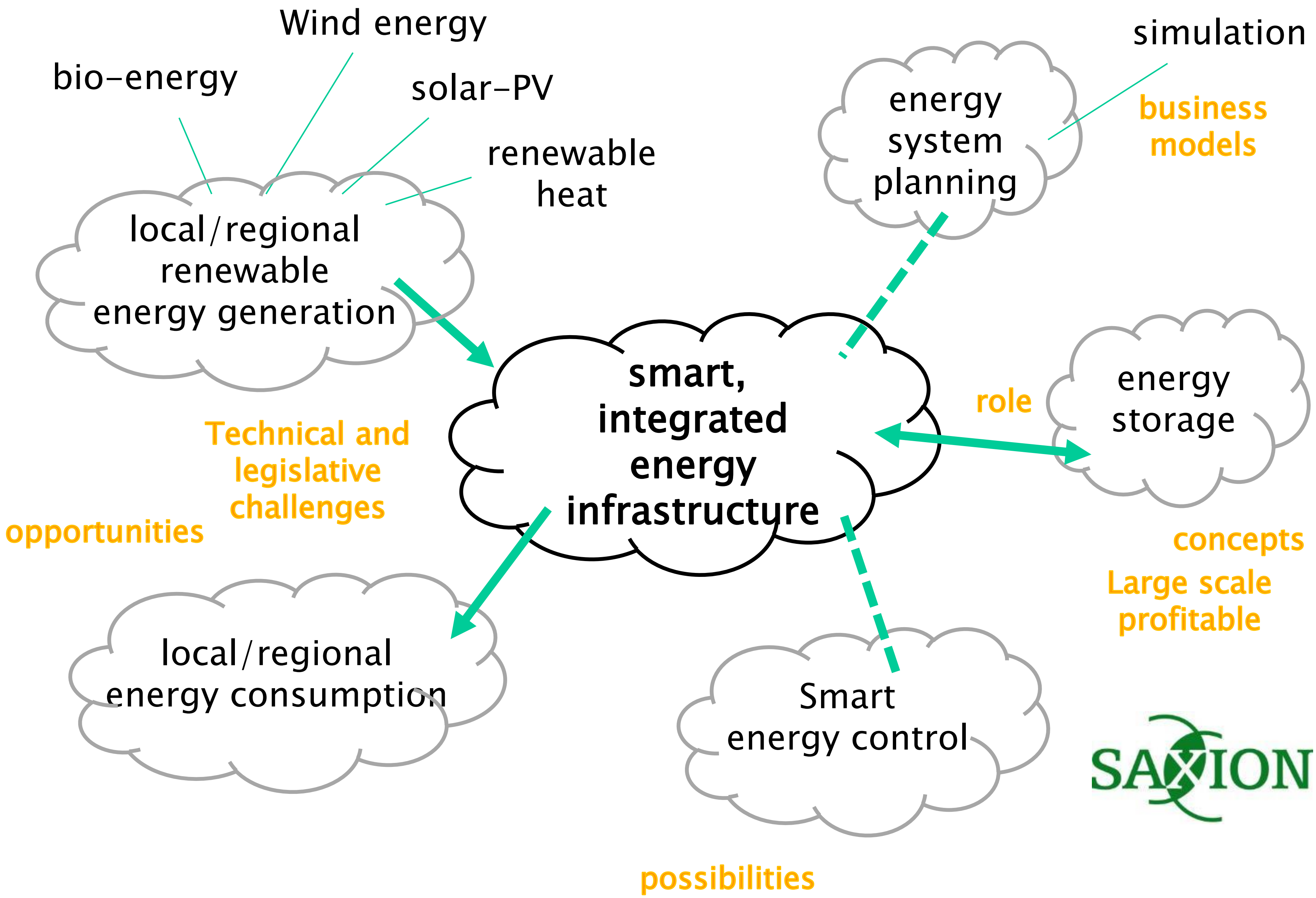
- Planning and control of storage and flexibility in micro-grids
- Planning and control of energy streams in buildings
- Measurements and control of power quality in micro-grids

More: www.utwente.nl/energy

# Focus of research chair renewable energy Saxion University of Applied Sciences

1. Bio-based economy and energy from biofuels
2. Smart buildings and energy control
3. Urban energy and integration of renewable energy





Wind energy

bio-energy

solar-PV

renewable heat

local/regional renewable energy generation

simulation

energy system planning

business models

**smart, integrated energy infrastructure**

role

energy storage

Technical and legislative challenges

opportunities

concepts

Large scale profitable

local/regional energy consumption

Smart energy control

possibilities

# WIEfm: modernizing heat supply in the Euregio

... de Euregio Gronau-Enschede, ...

INTERREG
Deutschland
Nederland

Fachhochschule
Münster University of
Applied Sciences

SAXION

Kom verder. Saxion.

# More information: www.wiefm.eu

WiE$^{fm}$ ist ein deutsch-niederländisches Projekt, das über das INTERREG-V-A-Kooperationsprogramm gefördert wird.

Bevorstehende Veranstaltungen

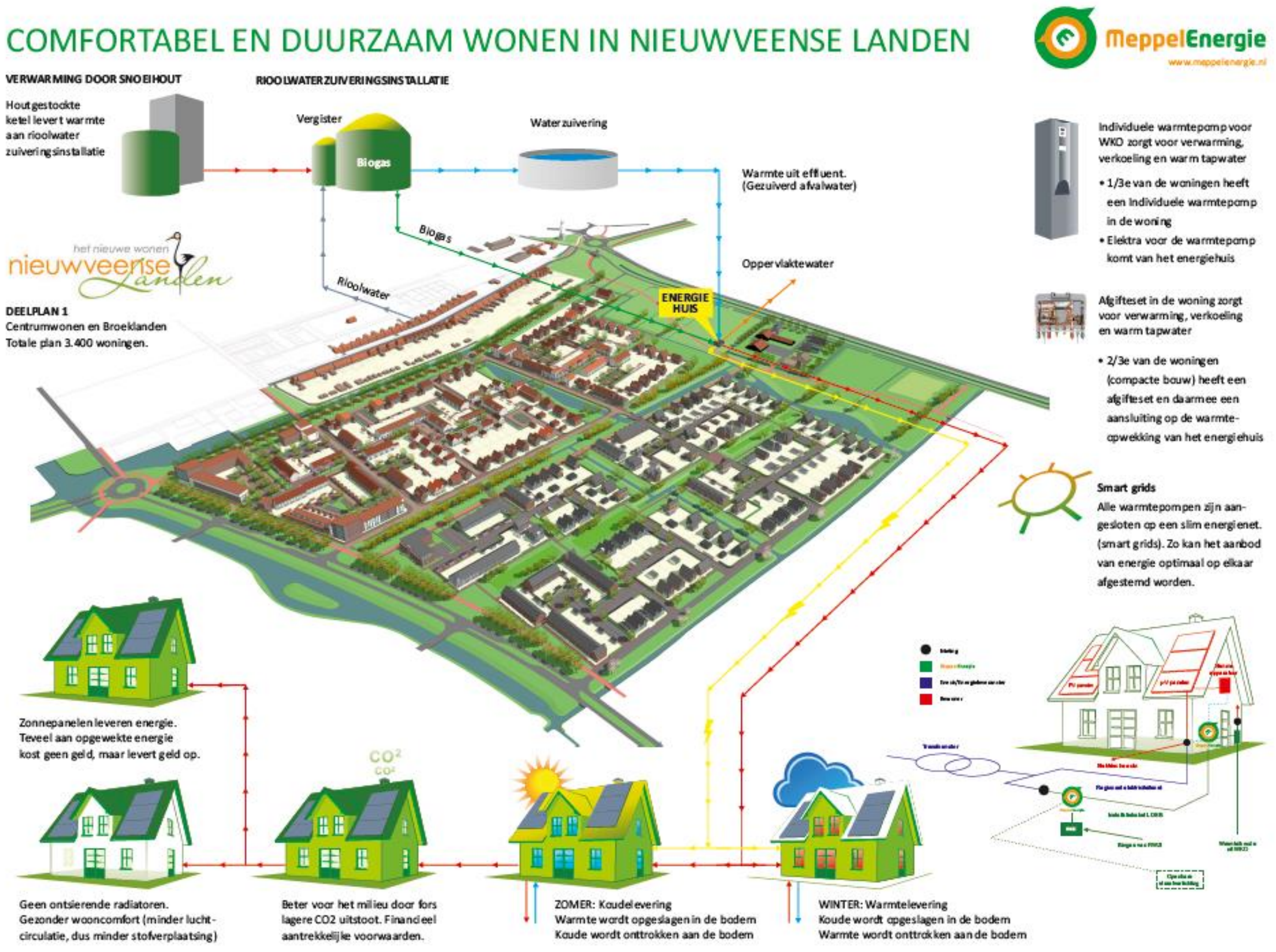
2nd International Conference on Smart Energy Systems and 4th Generation District Heating

27. September - 8:00 bis 28. September - 16:00

2. Expertenworkshop: Wärme aus erneuerbaren Energien

4. Oktober - 13:00 bis 18:00

# Case: Smart Grid Meppel Energie



## COMFORTABEL EN DUURZAAM WONEN IN NIEUWVEENSE LANDEN

**VERWARMING DOOR SNOEIHOUT**

Houtgestockte ketel levert warmte aan rioolwater zuiveringsinstallatie

**RIOOLWATERZUIVERINGSINSTALLATIE**

Warmte uit effluent. (Gezuiverd afvalwater)

**DEELPLAN 1**
Centrumwonen en Broeklanden
Totale plan 3.400 woningen.

Individuele warmtepomp voor WKO zorgt voor verwarming, verkoeling en warm tapwater

- 1/3e van de woningen heeft een Individuele warmtepomp in de woning
- Elektra voor de warmtepomp komt van het energiehuis

Afgifteset in de woning zorgt voor verwarming, verkoeling en warm tapwater

- 2/3e van de woningen (compacte bouw) heeft een afgifteset en daarmee een aansluiting op de warmte-opwekking van het energiehuis

**Smart grids**
Alle warmtepompen zijn aangesloten op een slim energienet. (smart grids). Zo kan het aanbod van energie optimaal op elkaar afgestemd worden.

Zonnepanelen leveren energie.
Teveel aan opgewekte energie kost geen geld, maar levert geld op.

Geen ontsierende radiatoren.
Gezonder wooncomfort (minder luchtcirculatie, dus minder stofverplaatsing)

Beter voor het milieu door fors lagere CO2 uitstoot. Financieel aantrekkelijke voorwaarden.

ZOMER: Koudelevering
Warmte wordt opgeslagen in de bodem
Koude wordt onttrokken aan de bodem

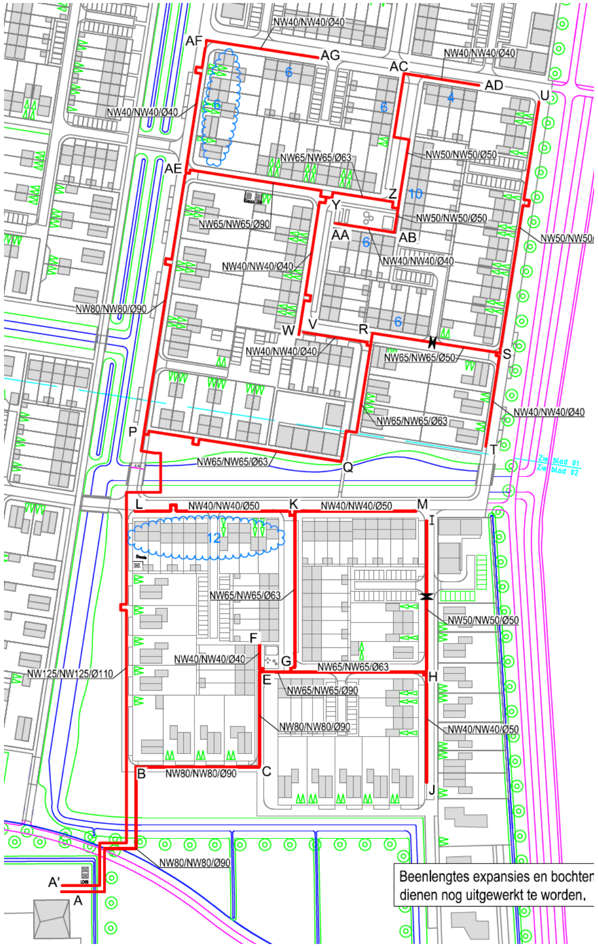
WINTER: Warmtelevering
Koude wordt opgeslagen in de bodem
Warmte wordt onttrokken aan de bodem

# Optimal district heating supply temperature

**Assumptions**:

- 200 houses
- Existing network designed for $70^{o}$C
- Present supply temperature: $80^{o}$C
- Joined return: 20-$35^{o}$C (average: $25^{o}$C)
- Specified pipe lengths, diameters and insulation thickness
- Flow calculation available at $70^{o}$C

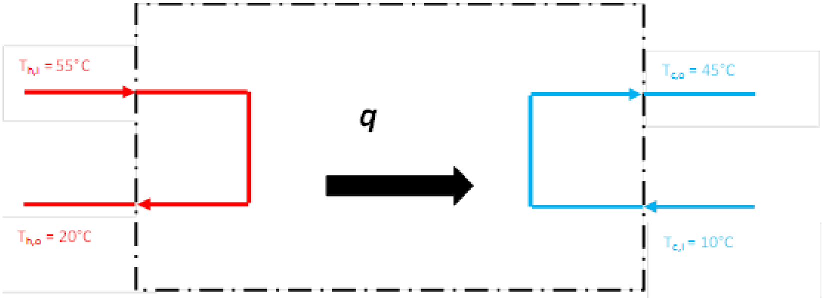
→ *Determine the optimal supply temperature*



Beenlengtes expansies en bochten dienen nog uitgewerkt te worden.

# Approach optimal supply temperature

1. Investigate feasibility of decentral temperature boost → *negative*
2. Investigate home heat exchanger transfer limitations

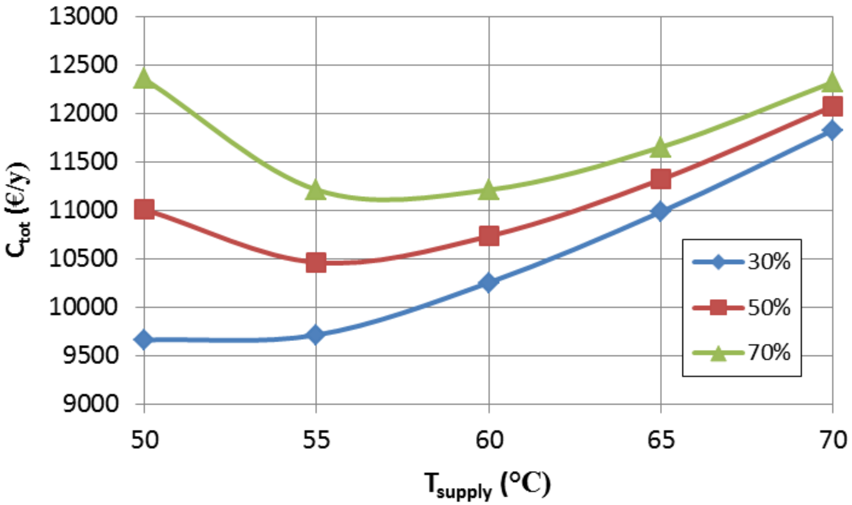


$T_{supply,min}=55^oC$

3. Develop models:
   - aggregated heat demand (time series)
   - pumping energy: $P_{pump}=f(\Phi_{max},T_{supply})$
   - network heat loss: $Q=f(T_{supply})$
4. Determine optimal supply temperature as cost minimum
5. Develop legionella risk reduction measures

# Optimal supply temperature

- Apply costs: pumping electricity: *€0,15/kWh*, heat loss *€0,03/kWh*
- Energy costs: equivalent full load hours/year: $t_{pump,max}$*/8760*



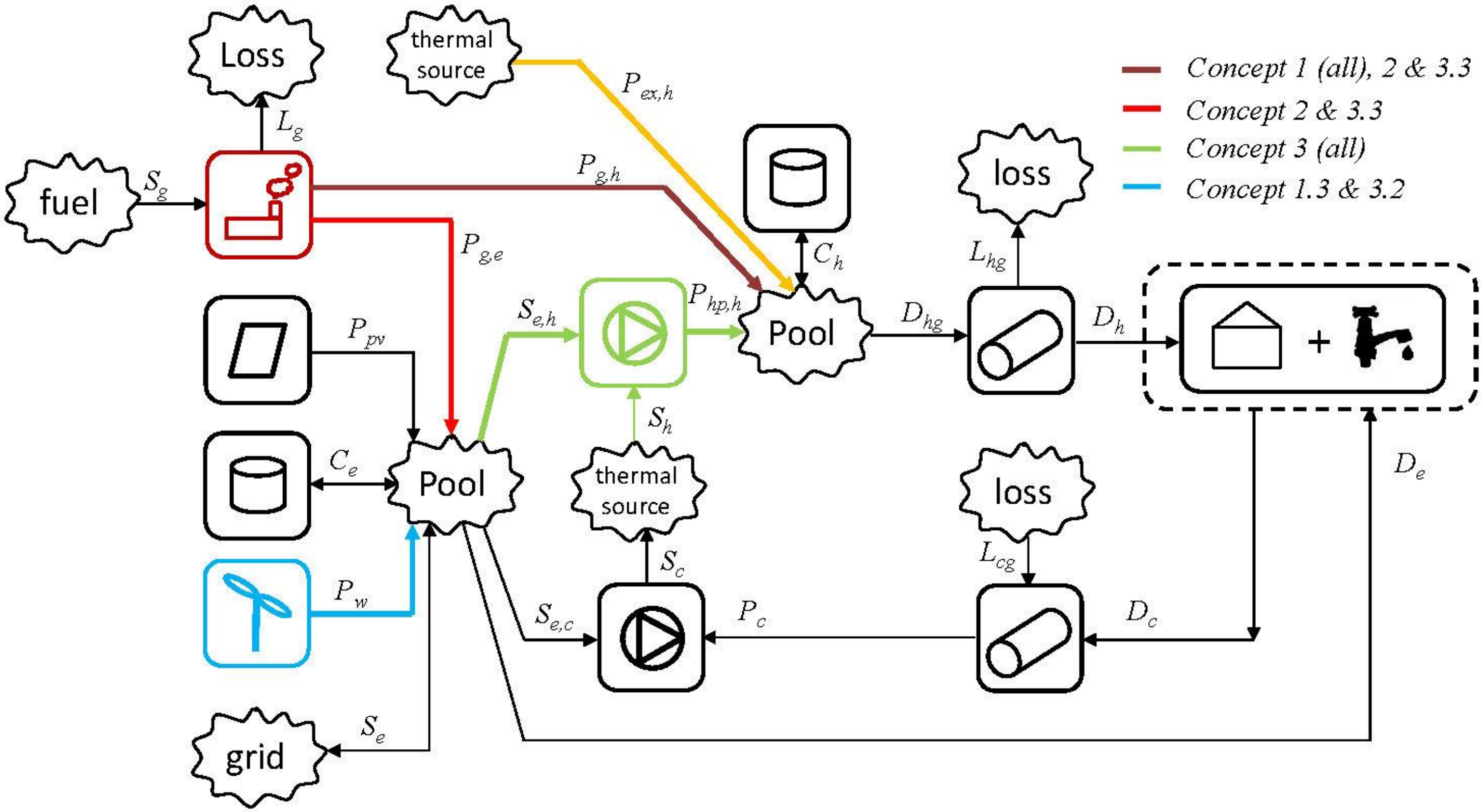
- Practical range: 25-40% for equivalent full load hours
- Include marging of e.g. 5$^o$C to guarantee supply furthest string

*conclusion: 60$^o$C*

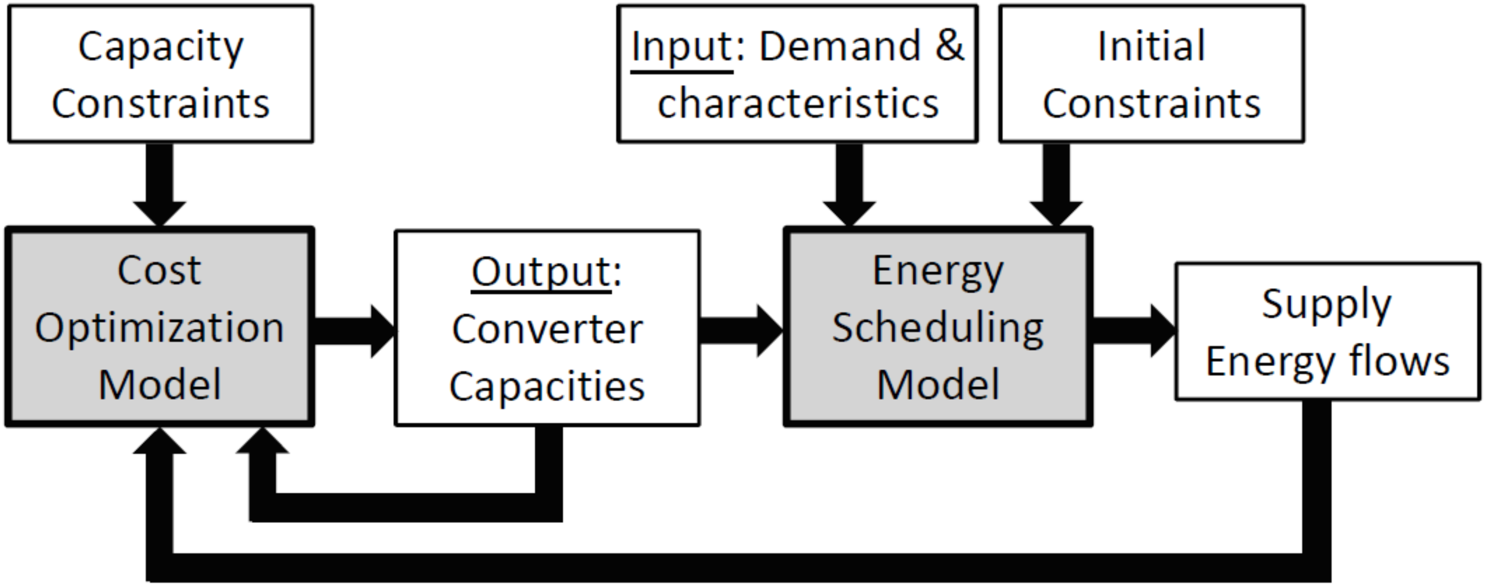
## Comments

- Practical experience: less pumping energy than expected → real optimum is at lower temperatures!
- Limitation Meppel case: T < 55°C causes problems for domestic hot water
- Dynamic flow and heat loss calculation to improve design of the district heating system
- Refer to papers by: Atli Benonysson, Henrik Madsen, Jan Hensen.
- Software for dynamic district heating simulation: Termis, Modelica, TRNSYS, Matlab Simulink

# Urban energy generation capacities



# Optimization principle



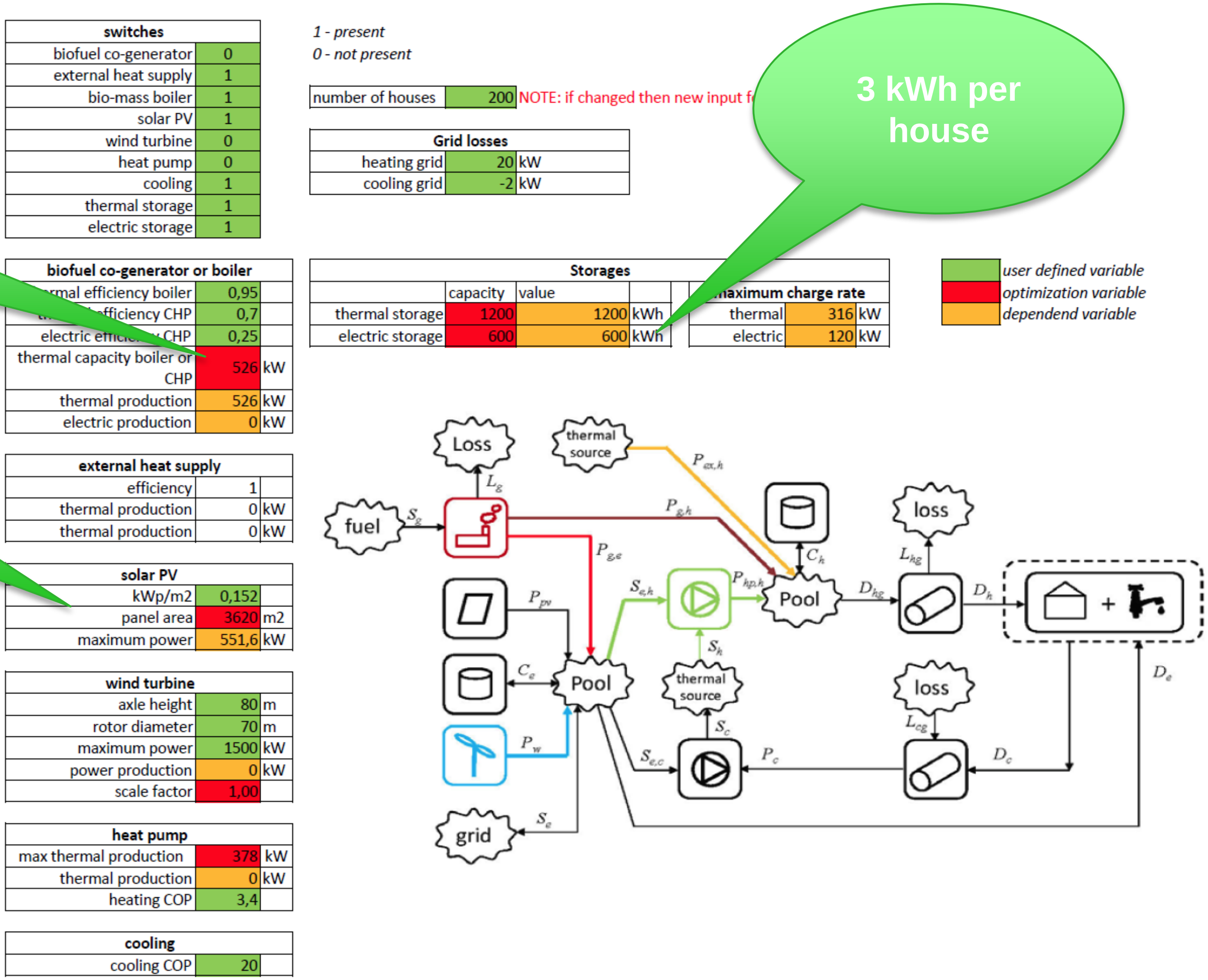
*More information: refer to upcoming paper related to this conference*

# Case study: Meppel with bio-fuel boiler & solar PV

- Reference: import (grey) electricity, condensing natural gas boiler per house, natural gas network
- Case:
  - Bio-fuel boiler with thermal storage
  - Supportive: external heat (natural gas boiler)
  - Large scale solar PV for household electric demand with electric storage

- Objective: maximize self consumption, minimize external heat
- Study influence of thermal and electric storage on objective and costs

# Dashboard with optimal capacities



| switches | |
|---|---|
| biofuel co-generator | 0 |
| external heat supply | 1 |
| bio-mass boiler | 1 |
| solar PV | 1 |
| wind turbine | 0 |
| heat pump | 0 |
| cooling | 1 |
| thermal storage | 1 |
| electric storage | 1 |

*1 - present*
*0 - not present*

| number of houses | 200 | NOTE: if changed then new input f |
|---|---|---|

| Grid losses | | |
|---|---|---|
| heating grid | 20 | kW |
| cooling grid | -2 | kW |

| biofuel co-generator or boiler | | |
|---|---|---|
| rmal efficiency boiler | 0,95 | |
| th efficiency CHP | 0,7 | |
| electric effic CHP | 0,25 | |
| thermal capacity boiler or CHP | 526 | kW |
| thermal production | 526 | kW |
| electric production | 0 | kW |

| Storages | | | | | | |
|---|---|---|---|---|---|---|
| | capacity | value | | aximum charge rate | | |
| thermal storage | 1200 | 1200 | kWh | thermal | 316 | kW |
| electric storage | 600 | 600 | kWh | electric | 120 | kW |

| | |
|---|---|
| 🟩 | *user defined variable* |
| 🟥 | *optimization variable* |
| 🟧 | *dependend variable* |

| external heat supply | | |
|---|---|---|
| efficiency | 1 | |
| thermal production | 0 | kW |
| thermal production | 0 | kW |

| solar PV | | |
|---|---|---|
| kWp/m2 | 0,152 | |
| panel area | 3620 | m2 |
| maximum power | 551,6 | kW |

| wind turbine | | |
|---|---|---|
| axle height | 80 | m |
| rotor diameter | 70 | m |
| maximum power | 1500 | kW |
| power production | 0 | kW |
| scale factor | 1,00 | |

| heat pump | | |
|---|---|---|
| max thermal production | 378 | kW |
| thermal production | 0 | kW |
| heating COP | 3,4 | |

| cooling | |
|---|---|
| cooling COP | 20 |

2.6 kWth per house

2.8 kWp per house

3 kWh per house

# Results

Compared to reference: 82% CO2 reduction

*Reference:*

Year totals (k h)

| Electricity | | | | | | | | Thermal | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| household electric demand | cooling electric demand | wind turbine production | solar PV production | CHP electric production | heat pump electric consumption | grid import | grid export | heat grid demand | biomass boiler or CHP thermal production | heat pump production | external heat supply |
| -576.449 | -7.313 | - | - | - | - | 583.762 | - | -1.692.617 | - | - | 1.692.617 |

| | generation-demand | import-export | storage balance | total balance |
|---|---|---|---|---|
| Electricity balance | -583.762 | 583.762 | 0 | 0 |
| Thermal balance | - | | 0 | - |

| | | |
|---|---|---|
| **grid peak** | export | 0 |
| | import | 174 |

Self consumption of solar PV: 57%

*Case:*

Year totals (kWh)

| Electricity | | | | | | | | Thermal | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| household electric demand | cooling electric demand | wind turbine production | solar PV production | CHP electric production | heat pump electric consumption | grid import | grid export | heat grid demand | biomass boiler or CHP thermal production | heat pump production | external heat supply |
| -576.449 | -7.690 | - | 583.604 | - | - | 251.799 | -251.566 | -1.867.817 | 1.868.404 | - | - |

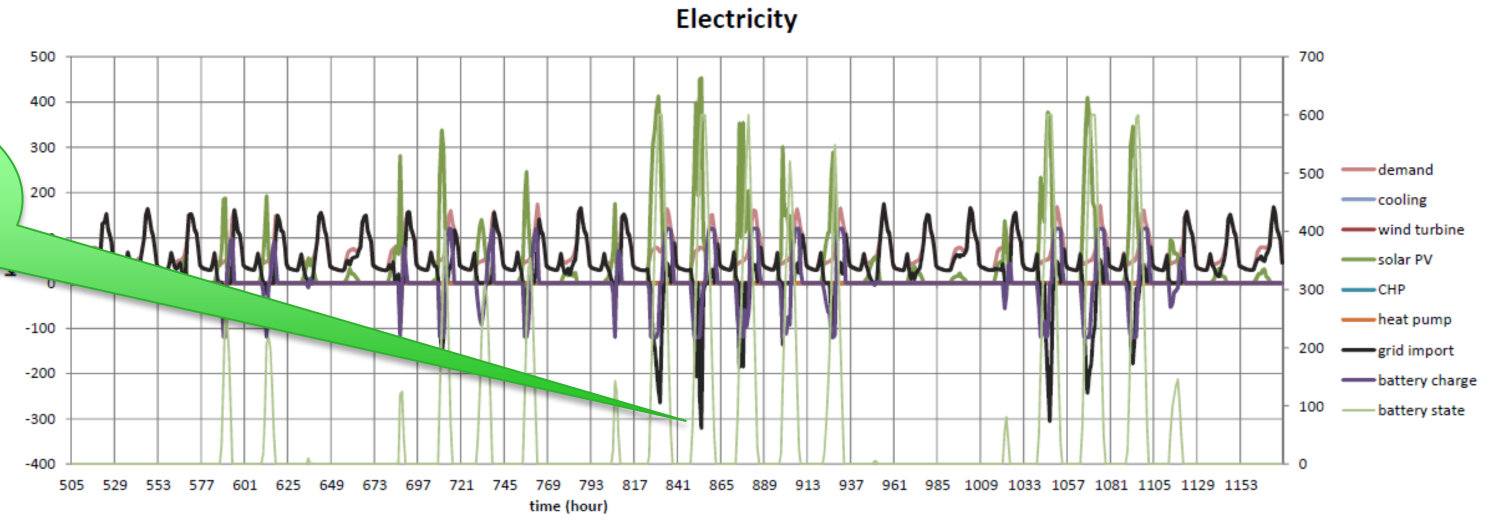
| | generation-demand | import-export | storage balance | total balance |
|---|---|---|---|---|
| Electricity balance | -534 | 234 | 300 | -0 |
| Thermal balance | 586 | | -586 | -0 |

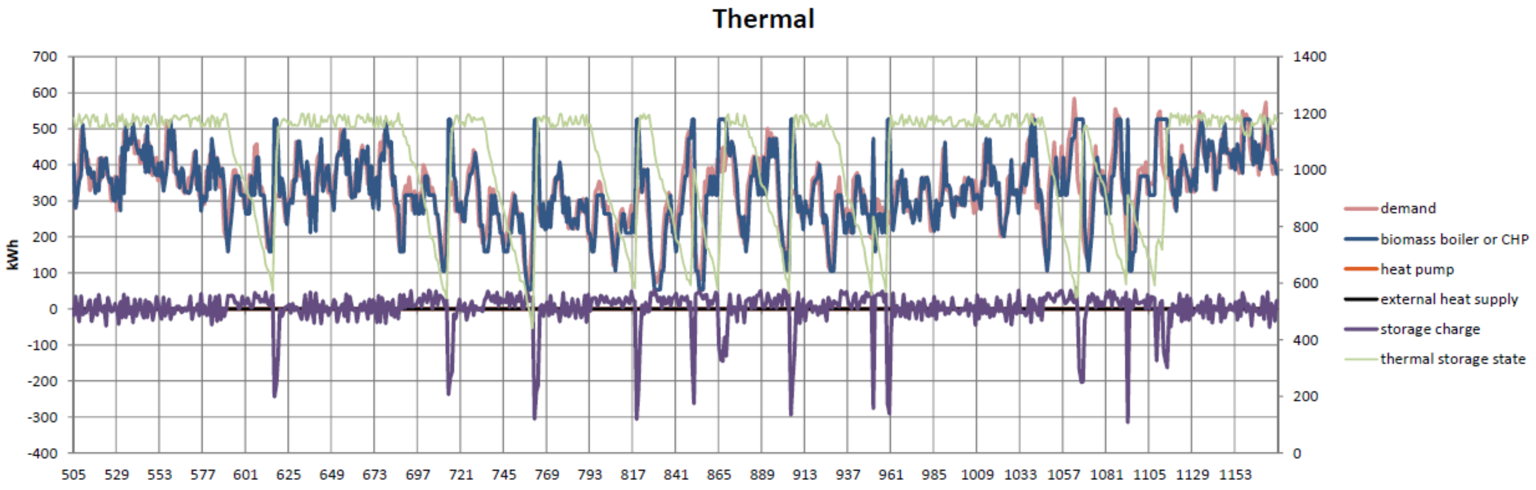
| | | |
|---|---|---|
| **grid peak** | export | -503 |
| | import | 174 |

Grid strengthening required

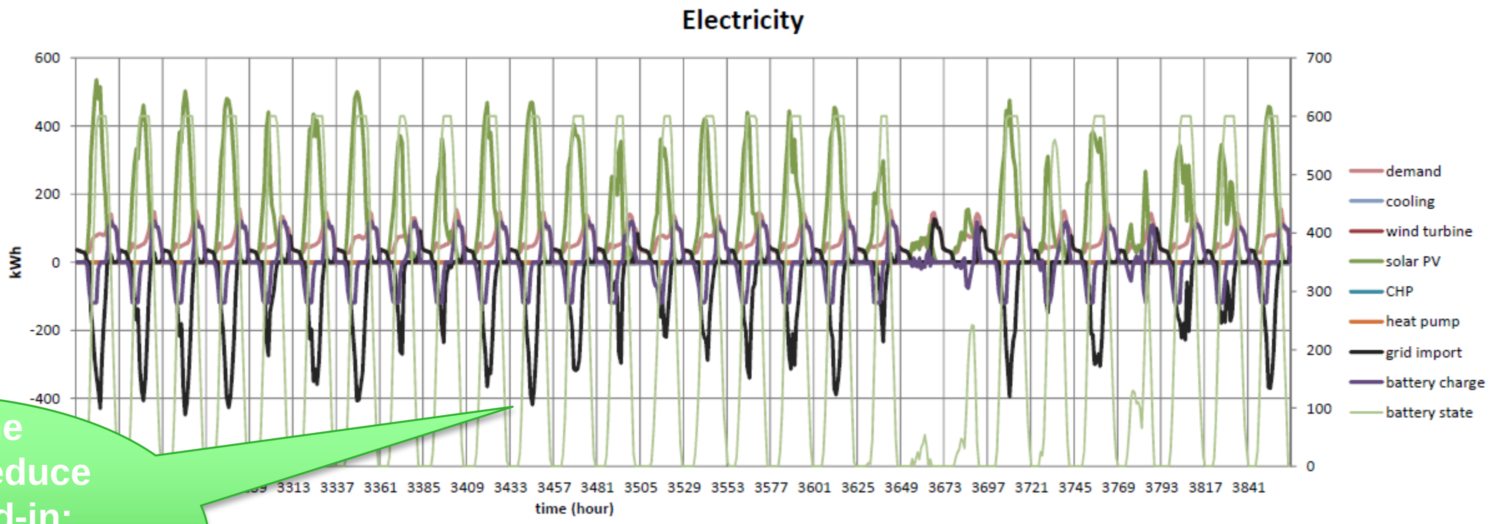
# 4 weeks January

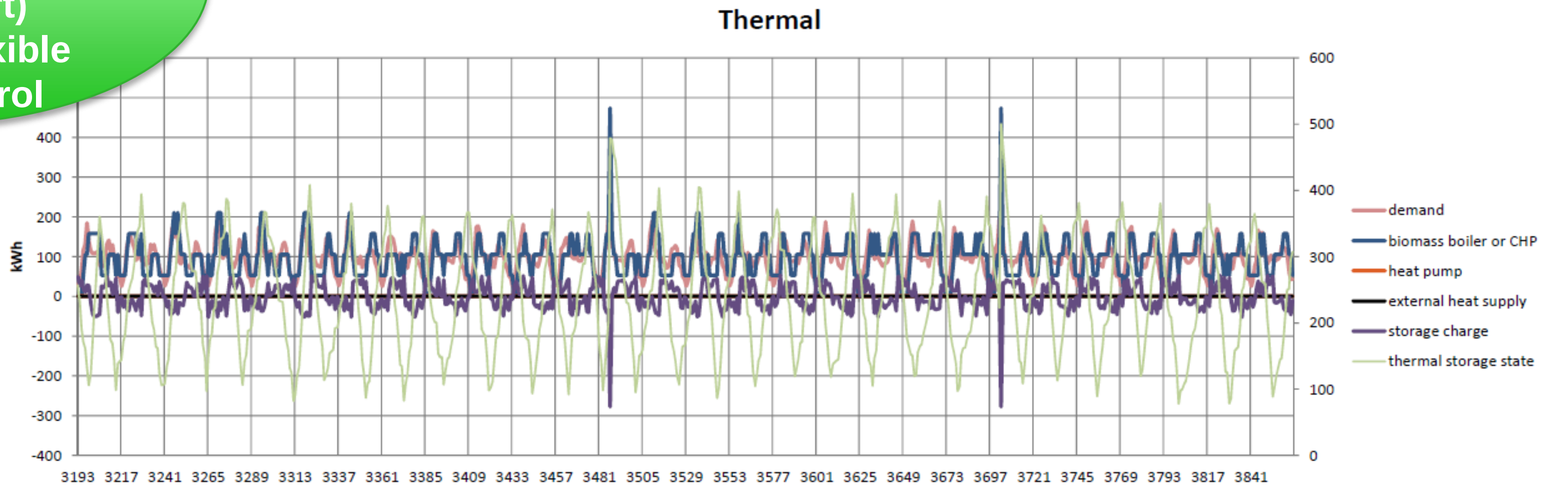
Storage alone does not solve grid feed-in peaks





# 4 weeks May

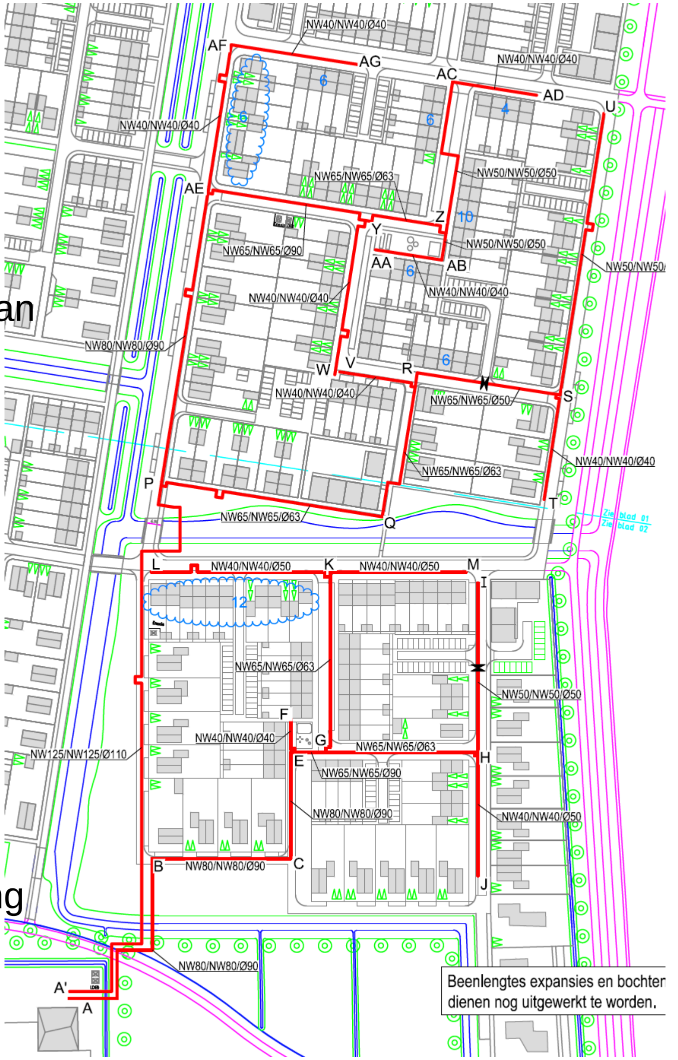




**Stand alone Solutions to reduce peak grid feed-in: MPC (smart) charging, flexible device control**

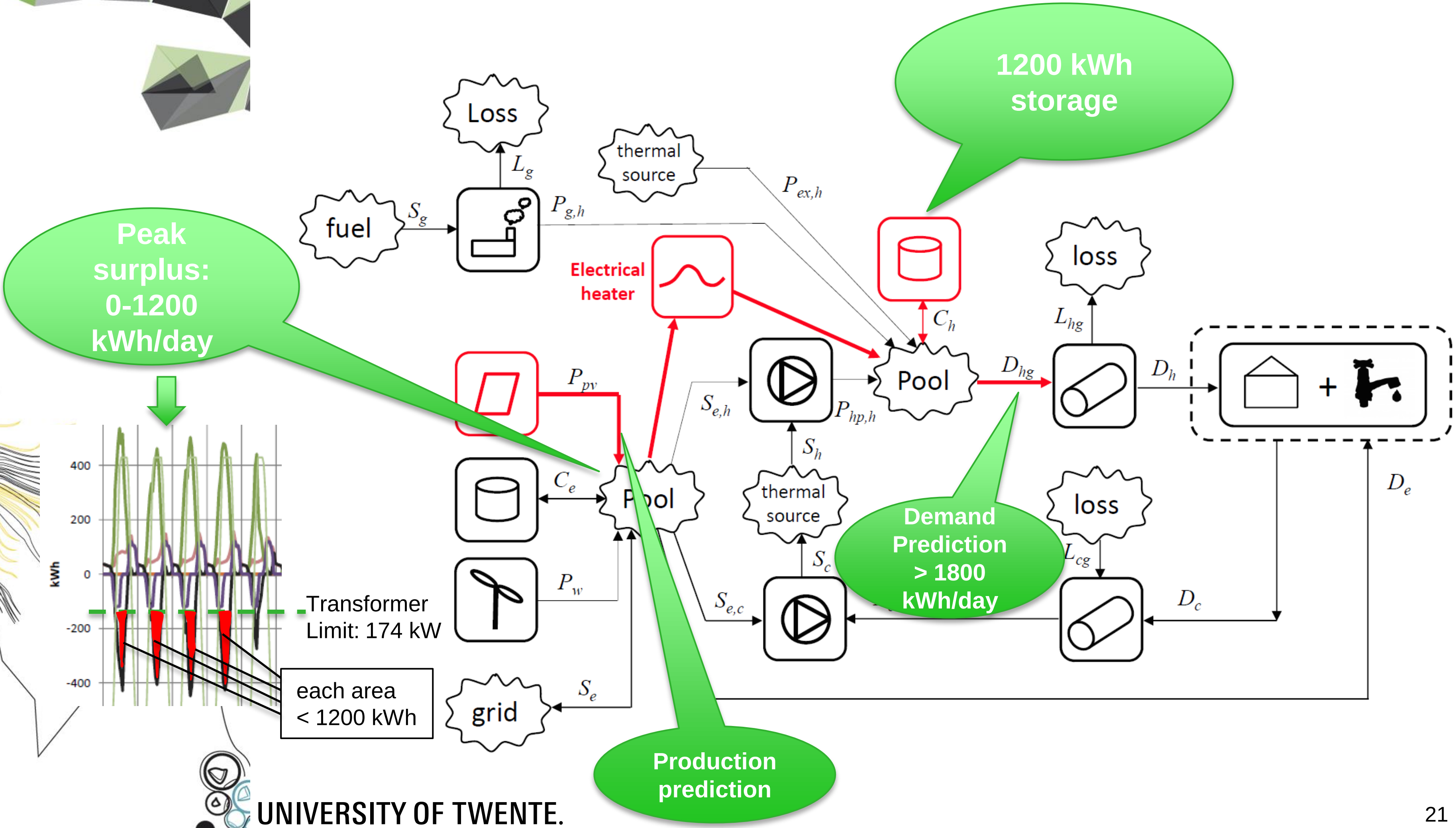
# Advantage of a district heating network for integration

- Dissipate surplus electricity into district heating network
- Price incentive:
    - Grid feed-in maximum: €0,055/kWh
    - Balance power market: feed-in revenues can be negative!
    - Fuel price wood chips: €0,023/kWh
- Is there a business case?
    - Cheaper connection (uni-directional)
    - No investments in other smart solutions required
    - Less electrical storage
    - More renewable feed-in possible for existing main grid capacity



Beenlengtes expansies en bochten dienen nog uitgewerkt te worden.

# How does it work?



**1200 kWh storage**

**Peak surplus: 0-1200 kWh/day**

Transformer Limit: 174 kW

each area < 1200 kWh

**Demand Prediction > 1800 kWh/day**

**Production prediction**

# What are the results?

Electricity:

- Household electric demand: -567 MWh
- Cooling electric demand: -8 MWh
- Solar PV production: 584 MWh
- Grid import: 252 MWh
- Grid export: -100 MWh

Thermal:

- Heat grid demand: -1868 MWh
- Bio-mass boiler production: 1716 MWh
- Electric conversion: 152 MWh

**Fuel savings: €3400/y**

**Increased Self consumption from 57% to: 82%**

Grid peaks:

- Export: -174
- Import: 174 kW

**Unstrengthened grid connection**

# Case study conclusions

**Optimal supply temperature of Meppel district heating system:**

- Pumping energy: pipe diameters & flow
- Heat loss: pipe insulation properties
- Minimum costs: 60$^o$C (≈ project limit)
- Opportunity: locally boost low (<55$^o$C) supply temperatures
- Legionella risk prevention for domestic hot water

**Optimal capacities of supply system:**

- Model for Optimal capacities → generators, storage facilities
- Interaction between demand and renewable generation flows
- Measures to reduce electricity peaks and limit surplus feed-in

**Advantage of district heating for system integration:**

- Opportunities: direct power to heat to reduce electricity peaks
- Attractive cost savings possible: fuel, grid lay-out & connections

# Thank you for your attention!

- More details on: www.utwente.nl/energy

  Electrical and thermal profile generators, PhD publications
- Online Thesis version expected: may 2017
- Future work, integrated tool:
  - Optimal capacities
  - Smart control of flexible devices

- Mail: r.p.vanleeuwen@saxion.nl